Wear your seat belts

- Seat belt
- Airbags
  - Head
  - Knee
  - Side
Mythbusters

Modern seatbelts, with force limiters will not give you the belt scar.

The seat belt will stop you from exiting the car

- Without the seat belt, the concussion will also stop you from getting out of the car

Airbags can hurt you

- If you are not wearing a set belt
- Seat is too close to the dashboard
- Passenger on the lap
Belt engineering

- Retractor mechanism
- Retractor locking
  - Car deceleration based
  - Belt pull based
- Pretensioner
  - Pyro based
- Load Limiter
Lot’s of online resources
A crash event

• What is the force required to stop the car if the crush is 1 ft?
• What is the force on the driver
  • With seatbelt?
  • Without seatbelt?
Force on car

- Mass of car = 1500 kg
- Velocity = 10 m/s (Usain Bolt is 11 m/s)
- KE = $\frac{1}{2}mv^2 = 75 \text{ kJ}$

**Tree:** 0.3 m stop

- $F_{avg} = \frac{KE}{\text{stopping distance}} = \frac{75 \times 10^3}{0.3} = 250 \text{ kN}$
- Stopping Time $\approx 0.06 \text{ s or 60 milli seconds}$

**Wall:** 2 m stop

- $F_{avg} = \frac{KE}{\text{stopping distance}} = \frac{75 \times 10^3}{2} = 32.5 \text{ kN}$
- Stopping Time $\approx 0.46 \text{ s or 460 milli seconds}$
No seatbelt

- The driver flies free until stopped by impact on the steering column, windshield, ..... 
- If the distance to impact is greater than stopping distance of the car, the car will be at rest or even bouncing back when the driver strikes it at the initial speed 
- The stopping distance of the driver is estimated to be less than 20 mm
Force on passenger without belt

- A car with 70 kg passenger crashes at 10 m/s and stops in 0.1 s.
- Estimate of car travel is $\frac{10}{2} \times 0.1 = 0.5 \text{ m}$
- Stopping distance = 0.02 m
- $KE = \frac{1}{2} \times 70 \times 10^2 = 3500 \text{ J}$
- $F_{avg} = -\frac{3500 \text{ J}}{0.02 \text{ m}} = 175 \text{ kN}$
- $a_{av} \approx 255 \text{ g}$
With seatbelt

- With a rigid seatbelt, the body travels as much as the car.
- Stretch in a seatbelt harness or force limiter
  - Extends the stopping distance
  - Reduces the average impact force on the.
- If the belt stretched 0.5 ft in the example car crash scenario it would reduce the deceleration to 20 g's and the average impact force to 3200 lb compared to 30 g's and 4800 lb for a non-stretching seatbelt.
- Any seat belt reduces the impact force compared to no seatbelt.
Passenger with belt

- A car with 70 kg passenger crashes at 10 m/s and stops in 0.1 s.
- Estimate of car travel is $\frac{10}{2} \times 0.1 = 0.5 \text{ m}$

- The average force exerted by the non-stretching seat belt exerts on a passenger is $F_{avg} = \Delta p / \Delta t$
- For the passenger we have $\Delta p = 0 - 700 \text{ kg} \cdot \frac{m}{s}$
- $F_{avg} = -\frac{-700 \text{ kg m}}{0.1 \text{ s}} = -7000 \text{ N} \quad a_{av} \approx 10 g$

- If the belt stretches by 0.25 m, stopping distance = 0.75 m
  - $KE = \frac{1}{2} \times 70 \times 10^2 = 3500 J$
  - $F_{avg} = -\frac{3500 J}{0.75 \text{ m}} = 4667 \text{ N}$
  - $a_{av} \approx 6.8 g$
Rollovers are complex

• Belt use
• Seated position with respect to the roll direction
• Other occupant loading
• The number of rolls.
ATD’s
Possible to escape them
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Source: NASS CDS, 1995 – 2001

- The sample included adult drivers and right-front passengers. All occupants were evaluated and then a subset of non-ejected occupants was analyzed.
- Using roll direction and seating position, the sample was divided into near- and far-seated occupants.
- Injury and fatality risks were determined by seatbelt use, occupancy, rollover direction, and number of quarter rolls. Risk was defined as the number of injured (e.g., MAIS 3+) divided by the number of exposed occupants (MAIS 0-6).
- Significance in differences was determined.
- A matched-pair analysis was used to determine the risk of serious injury for near- and far-seated occupants who were either belted or unbelted in the same crash.
Serious injury risks

- Highest for far-seated, unbelted occupants
- Near-seated unbelted occupants
- However, the difference was not statistically significant.
- Belted near occupants
- Belted far-seated occupants

- 18.1% ± 4.8%
- 12.0% ± 3.5%
- 4.3% ± 1.2%
- 4.0% ± 1.2%, respectively.
Ejection is a parameter

| Non-ejected, far seated, **unbelted** | 9.5%±3.2% |
| Non-ejected, near seated, **unbelted** | 4.9%±2.1% |
| Non-ejected, far seated, **belted** | 3.6% ± 1.1% |
| Non-ejected, near seated, **belted** |

Seatbelts were 64.2%–77.9% effective in preventing serious injury for all occupants.
Think of others as well

- An unbelted near-seated occupant increased the risk for a belted far-seated occupant by 2.2 times.
- An unbelted far-seated occupant increased the risk for a belted near-seated occupant by 10.2 times.
Number of quarter rolls

• Risk of serious injury increased with the number of quarter rolls, irrespective of seated position.
• For near-seated occupants, seatbelt effectiveness was higher in ≤ 1 roll than 1+ roll, at 72.3% compared to 28.3%.
• For far seated occupants, seatbelt effectiveness was similar in ≤ 1 and 1+roll samples at 78.3% and 76.8%.
• Occupants benefited from a technology intended for planar crashes and, in most instances, they fared very well.
• Analysis of rollovers by quarter turns indicates that occupants are both far-side and near-side in rollovers.
• This confounds the relationship between roll direction, seating position, and injury risk.
Fellow occupants

- In a rollover, the occupants are exposed to rotational velocity of $2\pi$ rad/s
- As a result, occupants move upwards and outwards
- In theory, occupants should not interact.
- But rollovers not only involve the roll phase, but they also include tripping and ground impact phases.
- Deceleration of the vehicle can lead to occupants loading other occupants and causing injury by occupant-to-occupant contacts.
- Restraint systems are effective in preventing this